

EGU General Assembly, Vienna, Austria – April 7-12, 2019

Chasing consistency: joint determination of terrestrial and celestial reference frames

Benedikt Soja*, Richard Gross, Claudio Abbondanza, T. Mike Chin, Michael Heflin, Jay Parker, and Xiaoping Wu

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States of America

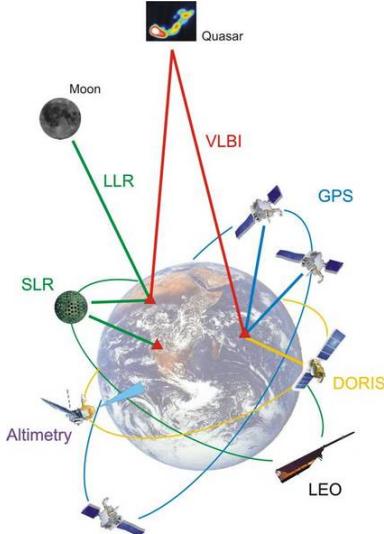
*bsoja@jpl.nasa.gov



Reference frames?

- Reference frames are realizations of coordinate systems
 - On Earth: terrestrial reference frames (TRF)
 - In Space: celestial reference frames (CRF)
- Connection (rotation) between TRF and CRF:
 - Earth orientation parameters (EOP)
- Determined from space geodetic observations
 - GNSS, VLBI, SLR, DORIS
- Benefits to science & society:
 - Sea level monitoring, navigation tasks, satellite operations, geodynamics,...

Reference frames need to be highly accurate



Inconsistencies between TRF and CRF



different inputs
multi-technique vs VLBI



different models
atmospheric loading

different definitions
scale

EOP are not the same for ITRF and ICRF

Solution: joint determination of TRF, CRF, and EOP

This talk: “chasing consistency”

– working toward and reaching this goal

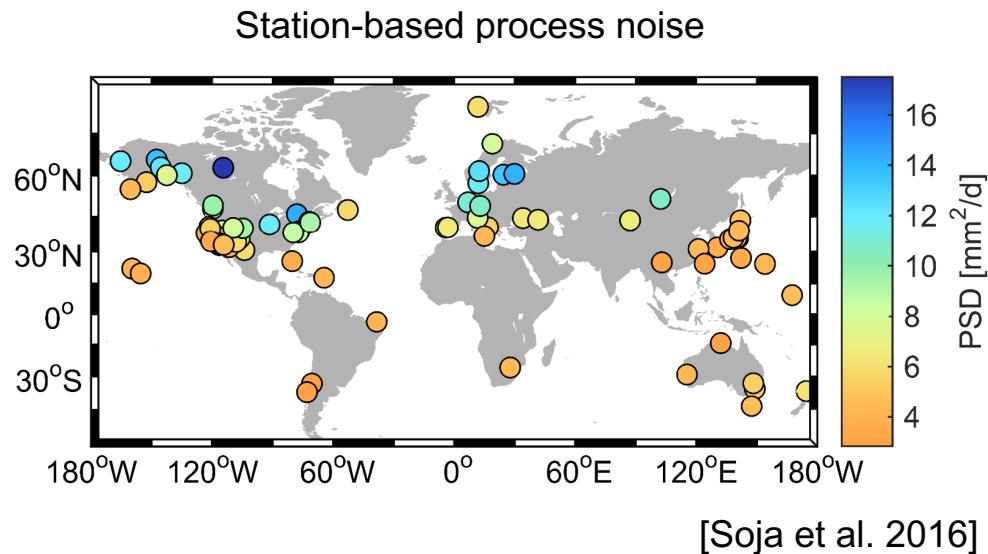
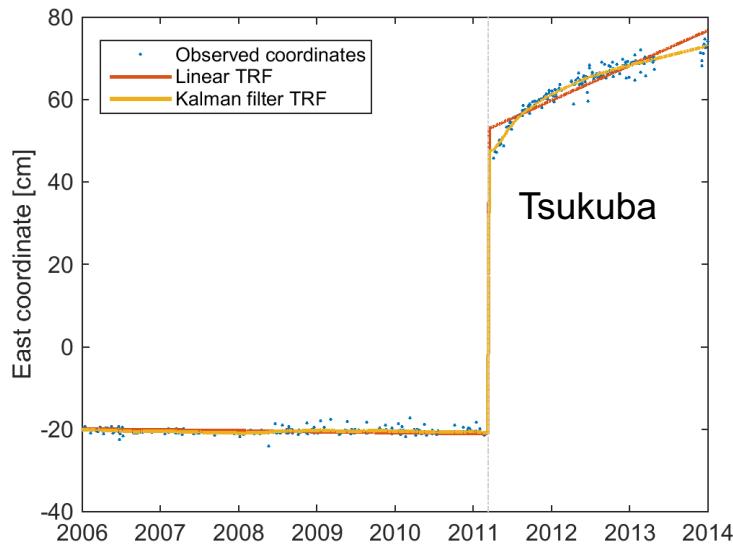
1. TRF determination
2. CRF determination
3. Joint determination

TRF determination



Kalman filter TRF approach

- TRF defined by coordinate time series (cf. Wu et al. 2015)
- Coordinate changes treated as stochastic processes
- Process noise based on geophysical processes
 - Loading displacements due to atmosphere, oceans, hydrology

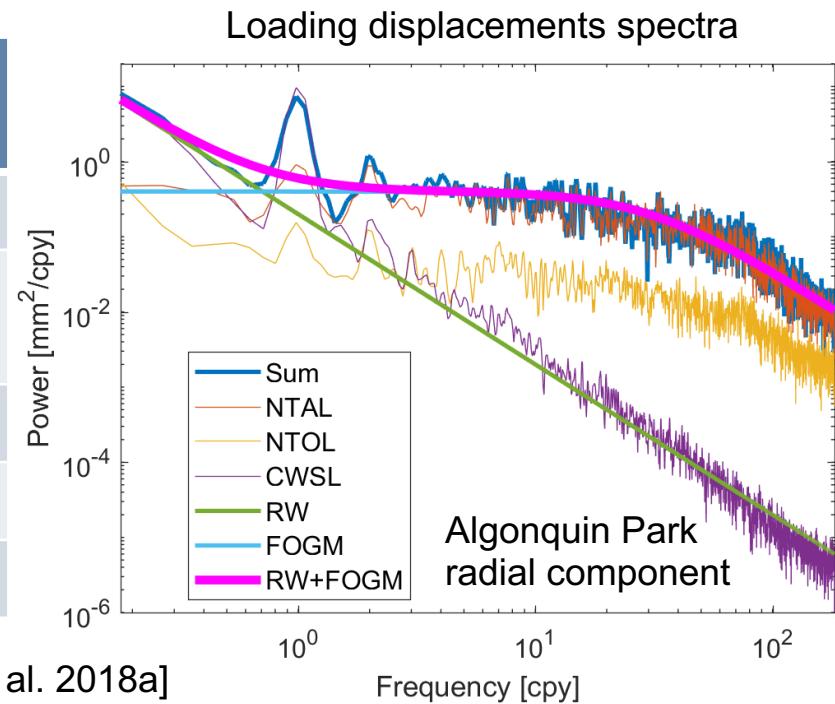


Effect of process noise on coordinates

- Selection of stochastic process and amount of process noise critical for TRF performance
 - Precision of coordinates and ability to predict future coordinates

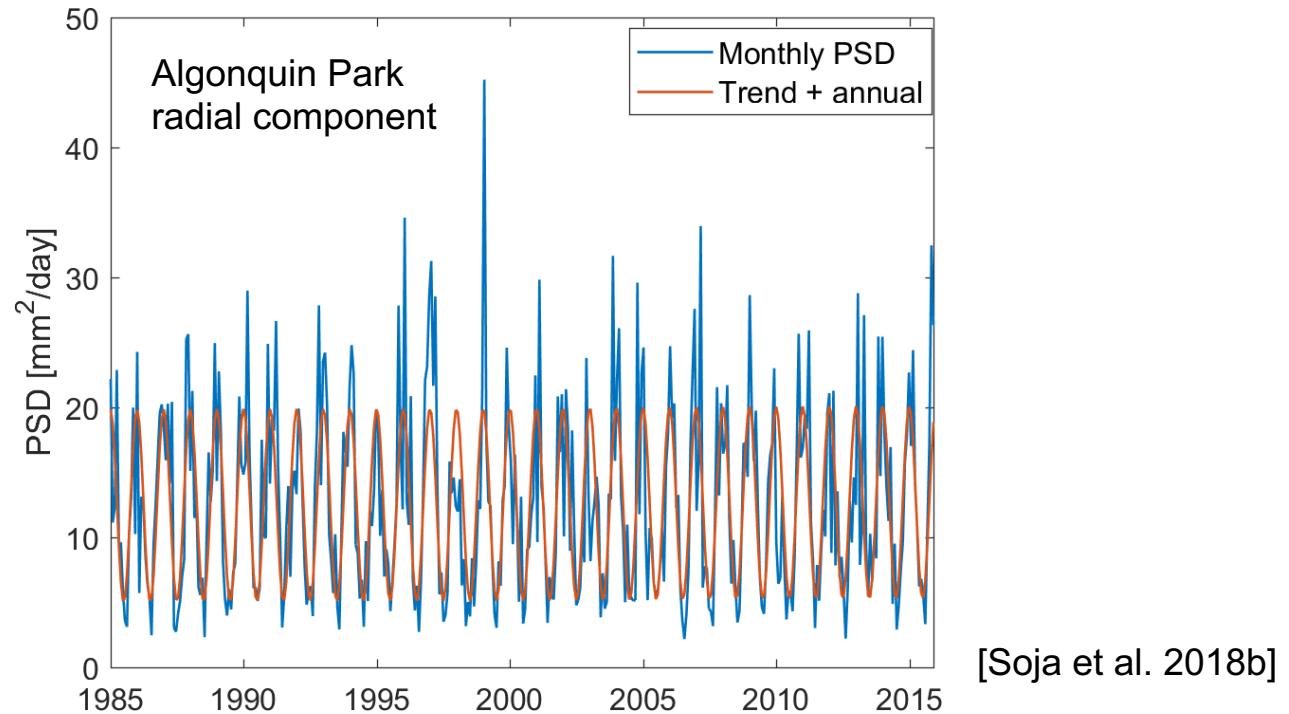
3-D WRMS [mm]	Coordinate precision	Predicted coordinates
Zero noise	14.0	15.1
Random walk	7.4	17.8
Scaled RW	10.2	15.8
White noise	11.4	15.1
AR(1)	10.7	15.0

[Soja et al. 2018a]

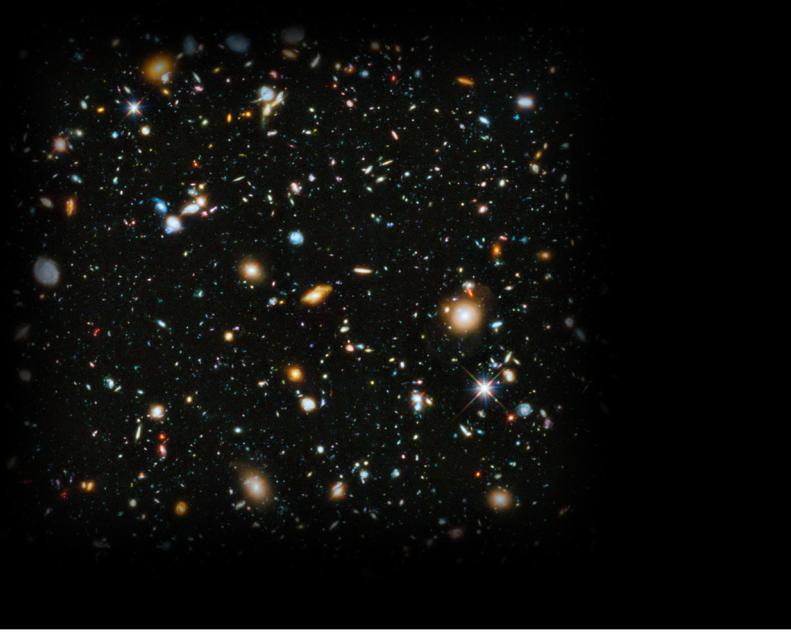


Time-dependent process noise

- Monthly determination of process noise values
- TRF coordinates differ by **up to 1 cm** between solutions with monthly and constant process noise models

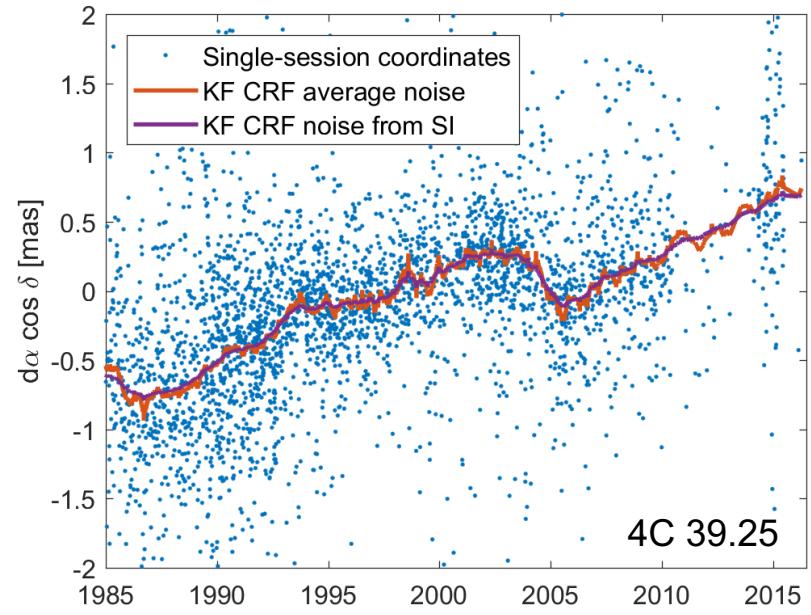
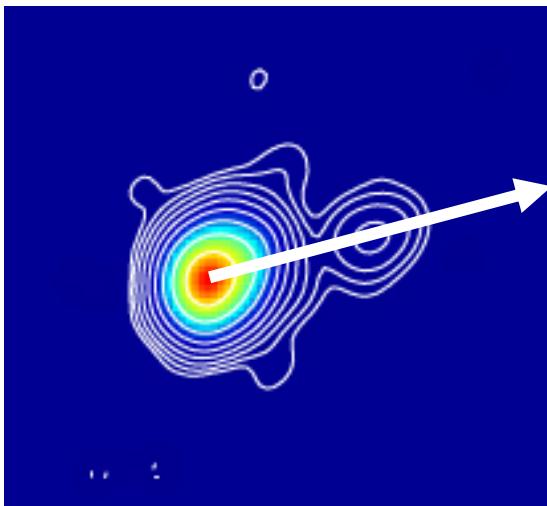


CRF determination



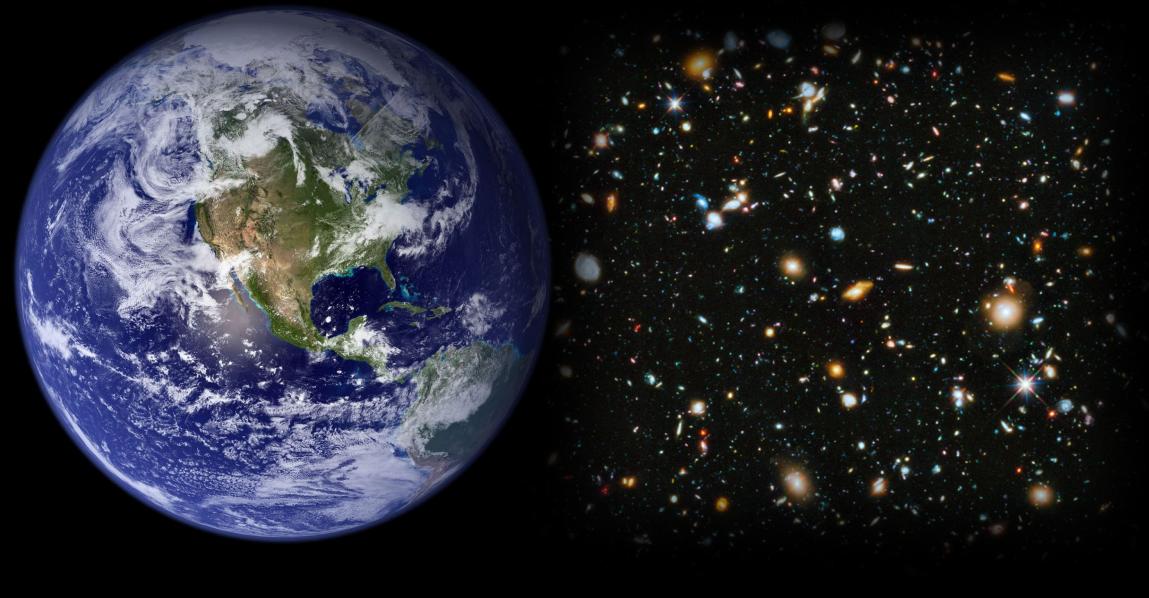
Kalman filter CRF approach

- Coordinates of radio sources subject to variations due to changes in source structure
- Process noise based on physical properties of radio sources, derived from radio source images
 - Jet direction, structure index



[Soja et al. 2017], [Soja et al. in prep.]

Joint TRF and CRF determination



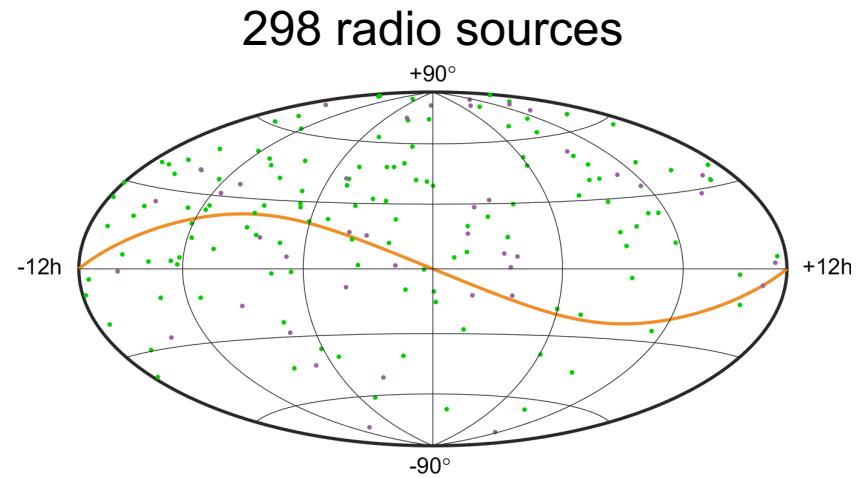
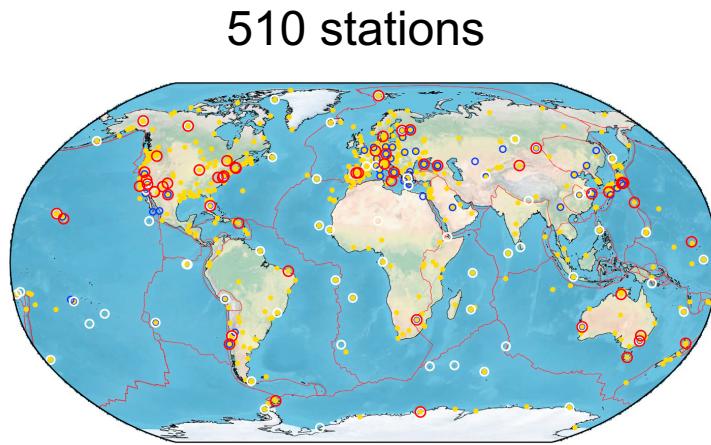
Methodology

- Connection between TRF and CRF:
EOP related to terrestrial (R_{xyz}) and celestial (A_{I23}) rotations

$$\begin{aligned}x_{p,t}^{obs} &= x_{p,t}^{est} + R_{y,t} \\y_{p,t}^{obs} &= y_{p,t}^{est} + R_{x,t} \\UT_t^{obs} &= UT_t^{est} - R_{z,t} \cdot r' + A_{3,t} \cdot r' \\dX_t^{obs} &= dX_t^{est} + A_{2,t} \\dY_t^{obs} &= dY_t^{est} + A_{1,t}\end{aligned}$$

Input data

- JTRF2014 (Abbondanza et al. 2014) reduced network for GNSS, SLR, and DORIS
- GSFC operational solution (*gsf2016a*) for VLBI



Results – transformations

- Helmert transformation w.r.t. ITRF2014

[mm]	Tx	Ty	Tz	λ	Rx	Ry	Rz
VLBI offset	-0.77	0.70	-1.65	2.81	0.31	0.05	0.26
VLBI rate [/yr]	-0.02	0.05	-0.09	0.13	-0.06	-0.02	-0.09
Comb offset	-0.03	-1.67	0.10	1.77	0.32	-1.24	6.92
Comb rate [/yr]	0.31	0.17	0.39	-0.67	3.84	-5.03	-13.49

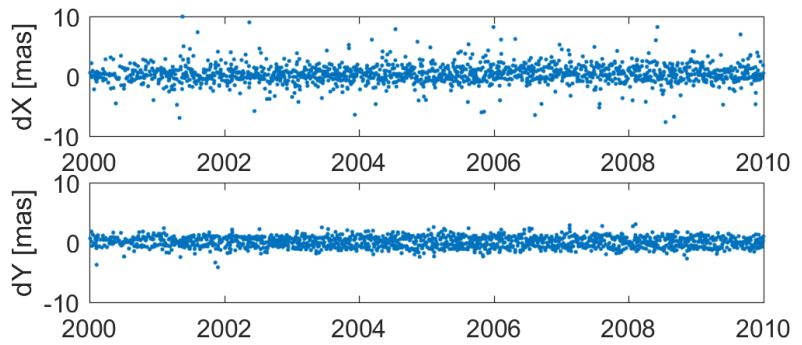
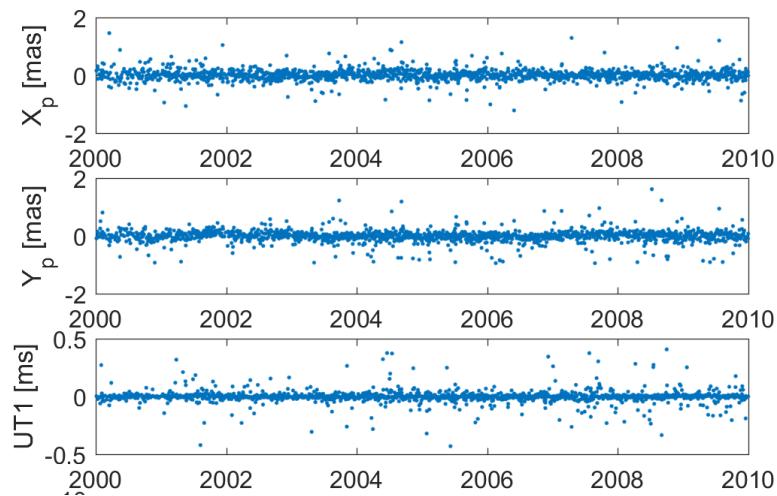
- Celestial rotations w.r.t. ICRF3

[mas]	A1	A2	A3
VLBI	0.143	-0.179	0.218
Comb	0.116	-0.158	0.232

EOP comparisons

- Difference w.r.t. IERS C04 14

RMS [mas]	x_p	y_p	UT1 [ms]	dX	dY
VLBI	0.26	0.25	0.062	1.66	0.91
Comb	0.24	0.21	0.062	1.66	0.91

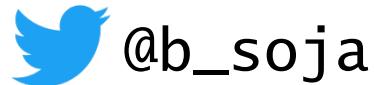


Conclusions

- Capability to **jointly estimate TRF, CRF, and EOP** established
 - Based on all four space geodetic techniques
 - Benefitted from research on Kalman filter approach to TRF and CRF determination
- **Consistency** chased realized; however, benefits difficult to evaluate when comparing to other frames
 - Application in geodetic analysis could be revealing
- **Outlook:** solution with full network and increased number of radio sources

Thanks for your attention!

bsoja@jpl.nasa.gov



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

Acknowledgements

B. Soja's research was supported by an appointment to the NASA Postdoctoral Program at the NASA Jet Propulsion Laboratory, administered by Universities Space Research Association under contract with NASA. U.S Government sponsorship acknowledged.